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Aquatic Photovoltaic Facility

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A feasibility design and cost estimate was completed for a 1 megawatt photovoltaic (PV) facility which would float on an inland reservoir at Catalina Island off the coast of Southern California. If built, this project would be one of the largest PV operating facilities to date and also the first floating PV system. The modular facility consists of 250 floating platforms each supporting 430 square feet of flat panel PV cells. This facility would provide 25% of Catalina's yearly peak energy demand and reduce the amount of diesel fuel used.

Santa Catalina Island is a mountainous little island 21 miles off the coast of Southern California. Currently, all of Catalina's electricity is produced by diesel generators, the fuel for which must be shipped by small barges from the California mainland. There is very little flat land on Catalina and the flat land available is protected under a conservancy. The only areas available for a photovoltaic (PV) facility are the two inland reservoirs. This facility is designed for the larger of the two, the Middly Ranch Reservoir, located about 7 miles from Avalon. This reservoir is about 650 feet wide by more than 3300 feet long, and when full, covers about 50 acres. During the dry season, the level of the reservoir can drop as much as 40 feet. During the rainy season, it can have as much as 7 feet of water flowing over a 50 foot wide spillway located at the northwest end of the reservoir.

System Characteristics

The proposed system is designed to be flexible and requires only that the site be bordered by land on one side. The sytem is modular in nature, so that it can be easily expanded in the future. Any unit of the array can be easily removed without upsetting the rest of the system, should drydocking or repair be necessary. The system is a regular array of identical platforms held together by a network of underwater mooring lines. The mooring lines are attached to the platforms by floating tubular legs. The system was designed so that all connections which have to be made can be made or broken above water to avoid the use of divers for installation or removal of the platforms (Fig. 1). To remove a platform, the floating tubular legs which are attached to the mooring lines are unbolted from the platform above water. The electrical connections are unplugged and the platforms can be floated away, while its tubular legs hold the moorning lines in place at the surface of the water. When the platform is ready to be returned, it is simply rebolted to the tubular legs.

Tracking Systems

In most applications, solar tracking with flat plate collectors is not cost effective. However, in this case, the water provided a built-in bearing surface and it was found that the system would track more cheaply than a land based system. Three different systems were studied: a fixed system, a one-axis tracking system, and a two-axis tracking system. The fixed system faces south. The one-axis system is basically the same as the fixed system, but includes a single motor, and a turnstile per row of platforms (Fig. 2). The motor rotates the turnstiles which are located on land. The mooring lines attached to the turnstiles will then rotate each platform about the vertical axis, allowing it to track the sun. The two-axis sytem uses a T-bar connected to the stationary horizontal mooring lines. While the T-bar remains stationary relative to the earth, it rotates about its vertical axis relative to the platform. A gear box and a couple of throws will then use this motion to change the angle of the tilt of the panel to track the sun in the vertical as well as the horizontal plane.

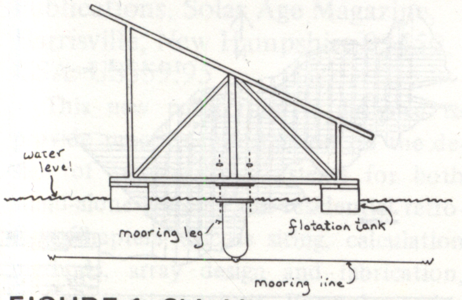

FIGURE 1: Side View of Platform Frame—Mooring Leg Detachment.

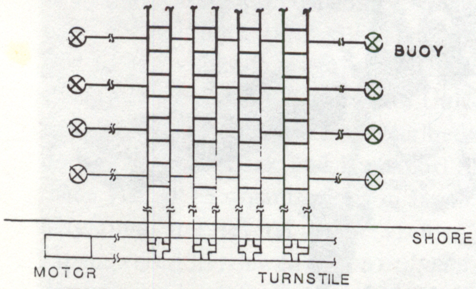

FIGURE 2: One-axis Tracking System.

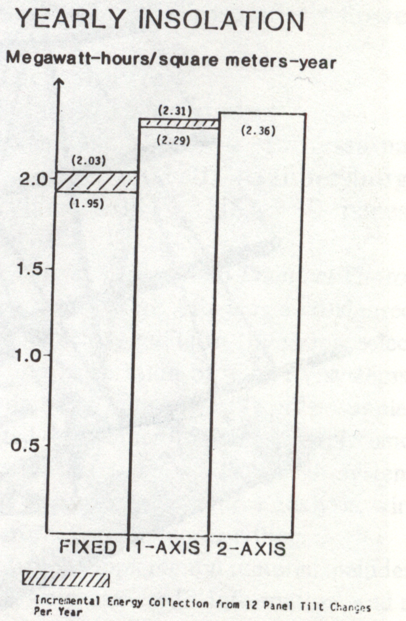

FIGURE 3: Energy Collection Characteristics of the Various Systems.

Solar Tracking Model

To determine the most cost effective of the three tracking systems, a computer simulation of each tracking system was performed. This tracking model used the Randall & Leonard method for separating the sunlight into its beam and diffuse components, and the Lui & Jordan method for calculating the light incident on an inclined panel.[1] Horizontal insolation data from Wrigley mountain on Catalina Island was used as the reference. The two-axis system proved not to be cost effective considering the extra cost of the gearing and hardware (Fig. 3). For the other two systems, changing the tilt manually during the year was considered. However, the incremental increase in energy (at most 5% for 12 changes/yr) did not offset the additional labor cost. Furthermore, the desired system was to be as maintenance-free as possible. Therefore, the non-tilting configuration was selected as optimum. Final designs were produced for both the fixed and one-axis non-tilting configurations. The tracking model was used to determine the optimal tilt angles of the PV panels and to compare the solar energy collection of each of the two designs.

Final Design

A model of the final design is shown in Figure 4. The structure is basically the same for the fixed and one-axis tracking modes, the main difference being the angle of inclination of the panel. The optimum tilt angles for energy collection are 25 degrees for the fixed and 45 degrees for the one-axis tracking system. Each platform is made of steel, measures 24 feet by 12 feet, and supports 430 square feet of PV collectors. Each platform unit produces 40 watts of DC power at peak output. This DC current is conducted to the shore where it is converted to AC current. The frame is made of two to three inch angle irons, square tubes, and structural tees. Flotation is provided by six plastic covered foam pontoons. The structure will remain afloat with only three pontoons present. The design wind load was 50 mph from the rear. The structure is also designed to withstand wave loading of one foot waves travelling at 10 feet/second. A structural safety factor of 4 was used.

A 1 megawatt, one-axis tracking array of 250 platforms takes up about 18 acres on the reservoir as shown in Figure 5. A fixed system takes up only two-thirds of this area since the fixed system cannot collect sunlight coming in from the East or West, so the panels can be spaced more closely in the east-west direction without any worry of shading. In both systems, a channel is left on the southern side of the reservoir to avoid shading by the mountains and to allow any floating debris to be swept out, over the spillway. A log line is required between the buoys along the eastern and southern sides of the array to keep debris away from the platforms.

Economic Evaluation

A PV panel cost of 70 cents per peak watt results in a total projected cost for an installed 1 megawatt system of \$3.7 million for a fixed system or \$4 million for a one-axis tracking system (in 1981 U.S. dollars). The one-axis system collects more energy. This extra energy is enough to overcome the extra initial cost and produce a lower levelized cost. Hence, corresponding levelized system costs of 42 cents/kWh for the fixed and 37 cents/kWh for the one axis tracking modes are obtained.[2]

Acknowledgement

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References

[1] J. F. Krieth and J. Kreider, *Principles of Solar Engineering*, McGraw-Hill, New York, 1978, pp. 79-82.

[2] D. S. Remer, C. P. Farmer, B. C. Kelly, H. T. Lim, M. L. Rieder, and R. H. Gurrola, *Harvey Mudd College Engineering Clinic Final Report to Southern California Edison*, Claremont, Ca. 1981, pp. 36-37.

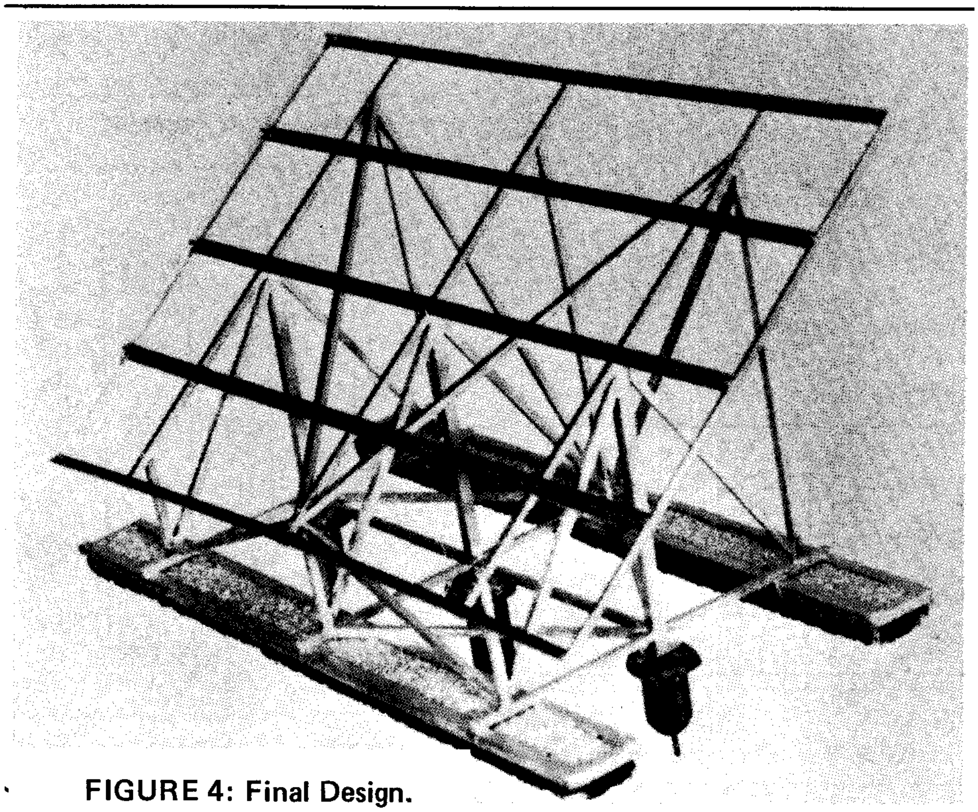

FIGURE 4: Final Design.

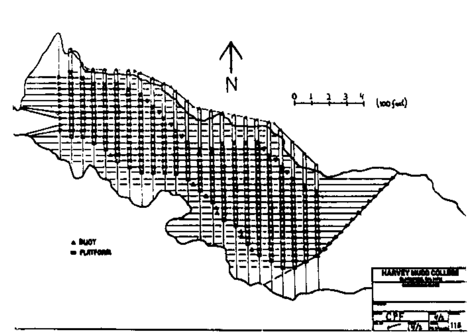

FIGURE 5: Middle Ranch Reservoir PV Array.